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Repowering—Next big thing in India

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ABSTRACT

Indian wind energy sector has seen a CAGR of more than 27% during the period 2002–2007. However, the annual capacity additions has been declining for the past 2 years and recently, India lost one place in the Global ranking on total installed wind capacity to China. While issues like unfavourable tariff, non-uniform state policies, unavailability of evacuation infrastructure, etc. can be attributed to the slower pace of capacity addition, the issue of unavailability of on-shore wind sites with sufficiently high wind velocity is expected to take centre stage in the next 2–3 years. Wind sites with low wind velocity make the investment unattractive to developers. Given the current situation, repowering as an investment option, which has already seen favourable response in countries like Germany and Denmark, would start maturing in India. This paper analyzes the present situation of the wind energy in India, evaluates the different wind energy market segments including repowering market, provides financial highlights of the repowering concept and ends with concluding remarks on major triggers which can set this concept in motion.

Contents

1. Wind energy in India

Wind power development in India started in the early 1990s when the feed-in-tariffs were declared by the Ministry of New and Renewable Energy, MNRE (called MNES as that time) and a package of fiscal and monetary incentives (100% accelerated depreciation, sales tax and custom duties concessions, buy-back guarantees, etc.) were put in place for the Renewable Energy (RE) sources. Since then the wind sector in India has grown to a current total installed capacity of more than 10,250 MW (*Source*: Ministry of Power (MoP)) on the back of more than 27% CAGR growth during the period 2002–2007. India presently ranks fifth in the world in terms of wind installed capacity (*Source*: REN21).

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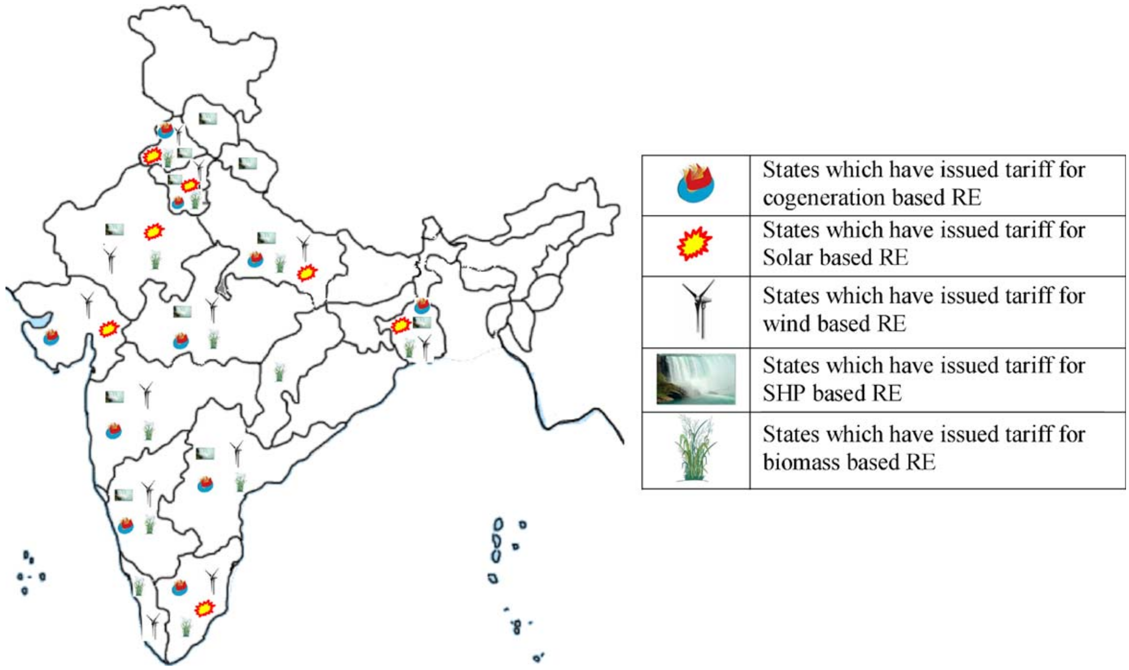


Fig. 1. RE sources for which feed-in-tariffs have been declared by SERCs.

Overtime wind energy market in India has matured from a subsidy driven market towards a more free market based environment. RE sources in the 1990s were solely supported by the subsidies announced by GoI. However, starting from 2000 onward the manner of support given to RE sources changed. Prior to enactment of the Electricity Act 2003 (EA 03), the State/Central Government was responsible for notifying feed-in-tariffs, however the State Electricity Regulatory Commissions (SERCs) are now responsible for notifying the feed-in-tariffs. In line with the functions laid down in the EA 2003, most of the SERCs (wind energy in 10 States, SHP in 11 States, biomass in 12 States, bagasse/Cogen projects in 9 States and solar projects in 6 States) as highlighted in Fig. 1 have come out with tariff orders declaring the tariff at which electricity generated through various RE sources would be purchased by the State utilities.

Also as per the Section 86 (1) (e) of the EA 03, SERCs shall specify a percentage of total electricity to be purchased by distribution companies from the RE sources. In line with this function, a total of fifteen States have specified the Renewable Purchase Obligation (RPO), i.e. the amount of RE (specified as a percentage of total energy consumption) which the distribution companies are mandated to procure from RE sources.

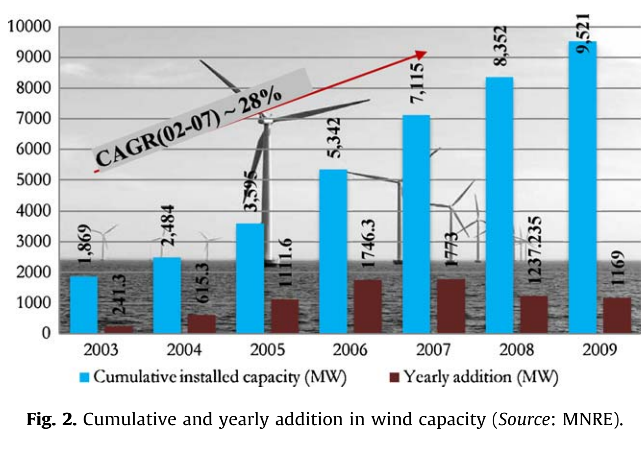


Fig. 2. Cumulative and yearly addition in wind capacity (*Source*: MNRE).

The results of the policy initiatives have been significant. India's wind energy sector has registered impressive growth and expansion between 1990 and 2006–2007, refer Fig. 2. The capacity addition during the 10th Five Year Plan (2002–2007) of 5731 MW was impressive, as only 1500 MW of capacity addition was planned during the plan.

2. Market segments

In this section, different market segments of the wind energy sector are discussed along with their present state of maturity. The idea is to talk about the untapped markets and discuss the available market opportunities in the Indian context.

2.1. On-shore market

The total on-shore wind energy potential in India is estimated to be about 48,561 MW. The total installed capacity for the on-shore market is more than 10,250 MW as of September 2009. With this installed capacity India is ranked 5th behind USA, Germany, Spain and China. The on-shore capacity is rapidly growing due to support from more and more SERCs who have notified economically attractive tariffs for the on-shore technology. Recently in 2009, CWET (Centre for Wind Energy Technology), agency responsible for assessing potential at different wind sites, has released information on wind potential in three additional States (Uttaranchal, Orissa and West Bengal) and the total potential available in India has been increased to 48,561 MW from 45,000 MW earlier, giving further boost to the on-shore market. The success of the on-shore market and the maturity of this particular market segment has led to not only private individuals looking at deploying wind generators for tax benefits but also large firms which are entering this space for several reasons like captive power consumption, attractive returns (in view of CDM benefits, REC trading, higher buy-back tariffs), etc.

Government policies are also helping this market segmentation positively. The availability of loans up to 70% of the total cost of the project, 80% depreciation in first year, zero import duty and tax holidays for new projects for 5 years are a few policies of the

Fig. 3. Visual depiction of repowering.

Government which are attracting new players in this sector. Government of India is mulling to set a target for meeting 10% of total power procurement from RE sources by 2012, most of which is expected to be met by the on-shore wind market.

However, the growth in on-shore market is expected to moderate in the coming years. Following reasons can be attributed to the decline in growth:

- *Lower wind velocity*: CUF (Cumulative Utilization Factor) at most of the wind sites available in India right now is between 16% and 18% which reduces the returns from the wind projects. Most of the regulators have determined the feed-in-tariff based on a CUF of about 22%[1] and hence wind sites with <18% CUF become economically unattractive. Some of the recently installed wind project are facing problems because the CUF at these projects have gone below 18%. While major players like Suzlon and Vestas would like to stress that there are still ample Greenfield sites with higher wind velocity in India, it is a matter of fact that players like WinWinD and Suzlon have recently (2009) launched Class 3 wind machines in the markets which basically run at less than 150 rpm and are suitable to work in low wind velocity conditions. This indicates the phase that the on-shore wind market is about to enter into.
- *Absence of evacuation infrastructure*: Untapped on-shore wind sites which are economically attractive due to higher CUF still remain unharnessed due to absence of evacuation infrastructure. These sites are present in areas which are remote and do not have a transmission grid or the transmission grid is not having the required capacity to evacuate the power generated. Technical potential of wind energy in India is less than 20,000 MW against a gross potential of more than 48,000 MW. One of the prime reasons for a wind site not being technologically exploitable is the absence of evacuation infrastructure at these sites.

2.2. Off-shore market

The off-shore market is the biggest untapped market for wind energy in India. India so far does not have a single off-shore wind machine installed; however the leading manufacturers (Suzlon and Vestas) in India are already manufacturing off-shore machines and exporting it to major international markets. So the access to technology is not a barrier to development of off-shore wind plants. The *Indian Wind Energy Outlook 2009* report talks about a possibility of wind energy contributing to 25% of India's energy requirements by 2030 and a major part would be played by the off-shore wind farms, something that holds great promise considering that India has a 7000 km coastline.

However in the medium term, the off-shore market does not seem to be an attractive proposition because of the following factors:

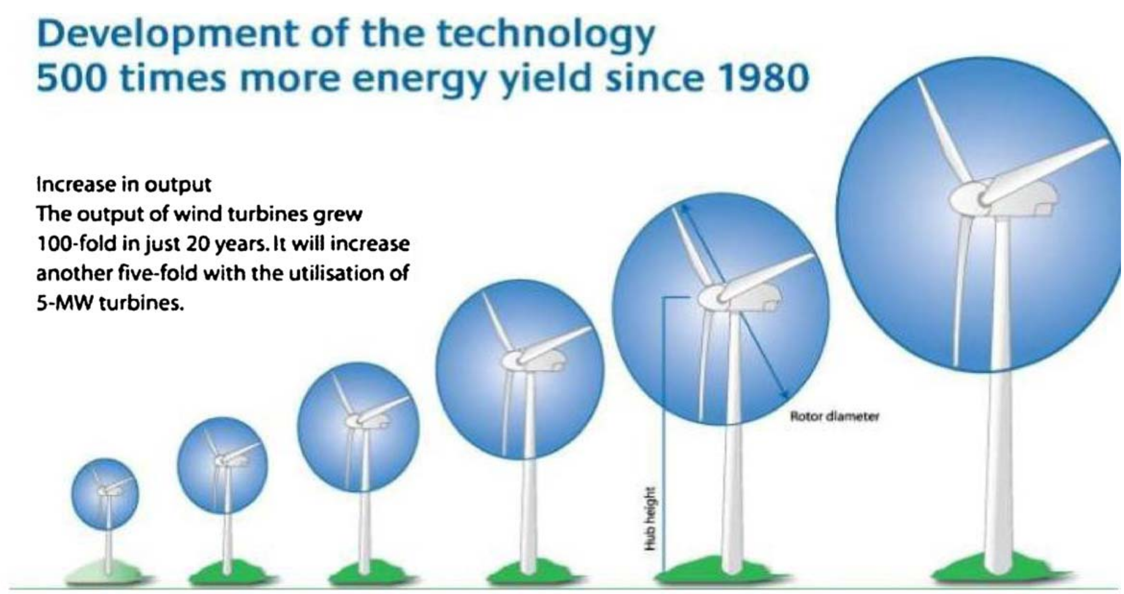
- *High capital cost*: Capital cost acts as the biggest barrier in development of the off-shore market in India. Typically the capital cost per MW for an off-shore wind machine would be between INR 150–200 million, which is quite prohibitive when compared to the cost of conventional technology at INR 35–45 million or even that of other green sources like on-shore wind (INR 55 million), SHP (INR 55–85 million), Cogeneration (INR 55 million), etc.
- *Policy/regulatory lag*: Even if the high capital cost of off-shore machines comes down, there would be a lag of 2–3 years due to the time taken, by the GoI and SERCs, for enactment of policies and regulatory orders which support the deployment of the off-shore technology. A parallel can be drawn from the on-shore wind market development, where approximately 3 years (2004–2007) were taken for a significant number of SERCs to come out with tariff orders to support buy-back from the on-shore wind market.

2.3. Repowering

Repowering stands for the replacement of old wind machines with more powerful and modern turbines. This means being able to generate more wind power from a lesser surface area. Different alternatives of repowering a wind machine are discussed in Appendix A for reference. Repowering as a concept is becoming an increasingly common feature in the European markets, especially in Germany and Denmark. A pictorial representation of a repowered wind site in Germany is presented in Fig. 3. Repowering presents an attractive opportunity to wind developers in India and the reason behind the same are discussed in this paper subsequently.

Wind energy generators in India have been installed prior to the year 1996. Technology access in India at that point of time was to machine size of 80 kW or 220 kW. Tariff in that period as notified by MNRE was only INR 1.92 per unit (not very high) and many wind generators were consuming the energy generated for captive use rather than selling it to the distribution companies. These old wind generators have operated for a period of over 10–15 years during which the developers would have recovered their entire invest-

[1] GERC has setup a benchmark CUF of 23% [3] and MPERC has setup a benchmark CUF of 22.5% [5].



	1980	1985	1990	1995	2000	2007
Nominal Power	30 kW	80 kW	250 kW	600 kW	1,500 kW	5000 kW
Rotor diameter	15m	20m	30m	46m	70m	115m
Hub height	30m	40m	50m	78m	100m	120m

Fig. 4. Timeline for access to technology internationally.

ment with returns. Currently in 2009, India has an access to technology with generating capacity of 2.1 MW and 3 MW and globally machines with capacity 5 MW were also available (refer Fig. 4), which can enable Indian wind developers to further capitalize on wind potential which could not be tapped earlier due to technological barriers.

As discussed earlier, SERCs of respective States have declared tariff order for wind energy sources. Tariffs have been determined by SERCs on a cost-plus basis (refer Table 1) and developers, which can work at a higher efficiency than the benchmarks set by SERCs, can attain a return which is higher than the assured Return on Equity (RoE) of 14%. Benchmarks for wind tariff includes a CUF of about 20% and since the CUF at the old sites are in the range of 28–32%, there is an opportunity to make more than the assured 14% RoE. Higher than assured RoE makes the proposition of investing in repowering even more attractive. Similar concepts have been highly successful in both Denmark and Germany (refer Section 6).

Table 1
A simplistic depiction of tariff determination process followed by SERCs.

Revenues
Generation (MUs) × tariff
Total revenues
Expenses
Interest charges
Depreciation
O&M expenses
Income tax
Return on equity
Total cost
Tariff (total cost/MUs generated)

The following sections highlight the States which have a potential market for repowering along with the detailed analysis of financial attractiveness of the repowering business.

3. Market size

This section highlights the States which have the market potential for repowering and lists down some of the potential sites (and clients owning these sites) which can be repowered. Typical attributes of a sites which can qualify for repowering are:

- *CUF*: Idea behind repowering is to focus on Brownfield sites which have CUF on the higher side, typically in the range of 28–32%. Not only will it help increase the amount of energy produced per unit area by deploying larger machines, a higher CUF would also make the proposition of investing in the repowering financially more attractive.
- *Condition of the wind machines*: Old wind machines, suffering from significant amount of downtime act as an attractive option for repowering. Interactions with experts in the wind markets reveal that a lot of wind project developers who had setup project prior to 1996 are facing problems due to machine downtime. Since the machine designs are old and the companies who had provided these machines are either no longer in business or not manufacturing the design in question, the availability of spare parts becomes a big issue. Consensus is that a lot of these site owners would be open to repowering (either to undertake repowering on their own or by selling out/forming JV to/with another investor) in another 2–3 years as they find it difficult to keep the wind machines operational.
- *Life of the wind project*: Typically sites which would be economically very attractive for repowering are the ones where

Table 2
Snapshot of owners who had installed wind machines prior to 1996 (list is not exhaustive).

S. No.	Name of owner	Location	Capacity (MW)	Year of commissioning
1	ABS Industries	Jamnagar	8.4	September 1996
2	Ahmedabad Strips Ltd.	Jamnagar	0.225	March 1994
3	Ajanta Transistors	Jamnagar and Rajkot	6.135	August 1997
4	Amol Decalite	Jamnagar	0.7	June 1995
5	Anic Steels Ltd.	Lamba, Jamnagar	1.575	September 1995
6	Antifriction Bearing Co.	Lamba, Jamnagar	1.35	March 1995
7	Apar Ltd.	Navadra, Jamnagar	2.5	March 1996
8	Alpha packaging Private Ltd.	Lamba, Jamnagar	0.2	September 1994
9	Arivand Mills	Navadra, Jamnagar	3	March 1995
10	Arun Udyog Ltd.	Navadra, Jamnagar	0.32	March 1996
11	Arunodaya Mills Ltd.	Lamba, Jamnagar	0.3	September 1995
12	Arvind Mills Ltd.	Navadra, Jamnagar	3.2	September 1996
13	Banco Products Ltd.	Rajkot	0.4	March 1995
14	Banco Aluminium Ltd.	Rajkot	0.8	March 1995
15	Baroda Electric Meters	Rajkot	0.3	September 1995
16	Bhagwati Spherocast	Kalyanpur Jamnagar	0.225	September 1996
17	Bhukanwala Diamand Tools	Risalka, Rajkot	0.2	March 1996
18	Choksi Tube Co.	Navadra, Jamnagar	1.84	March 1997
19	Cibatul Ltd.	Lamba, Jamnagar	2	March 1994
20	Colour Synth Ltd.	Mervadar, Rajkot	0.92	March 1995
21	Conart Engineers Ltd.	Risalka Rajkot	0.2	September 1995
22	Crown TV	Lamba, Jamnagar	0.225	March 1995
23	Dhariwal Industries Ltd.	Bhogat, Jamnagar	7.55	September 1996
24	Elecon Engineering Co. Ltd.	Jamnagar and Rajkot	10.45	September 1996–1998
25	Electric Control Gear	Jamnagar	0.7	September 1996
26	EMTICI Engineering Ltd.	Jamnagar	0.25	March 1994
27	GMM Ltd.	Jamnagar	1.8	March 1996
28	Gopy Synthetics	Jamnagar	0.225	March 1995
29	GSL Ltd.	Jamnagar	2.325	March 1995
30	Gujarat Gas Co	Jamnagar	3	September 1994
31	Gujarat Telephones	Rajkot	3	March 1996

Source: Directory, Indian Wind Power 2008, 8th edition.

the wind machines have been operating for more than 10–15 years as the investor would have recovered his investment and also earned returns from plant operations. Also, any project developed 15 years ago would have been amongst the first few and would have been developed on the best site available. So older the site, better the financial returns from repowering.

- *Location*: Location (State) of the wind site is important with respect to the tariff being offered by the State and the RPO applicable inside the State. Although the tariffs notified for all the States are high enough to ensure the financial attractiveness of repowering, it can be one of the criterion to evaluate the attractiveness of one State vis-à-vis another. Also, RPO is an important measure to gauge the demand for renewable energy inside the State as demand for RE sources in a particular State is primarily driven by the RPO level specified by the SERCs.

Evaluating different States based on the *key* parameters (wind machines installed prior to 1996 and CUF >28%) mentioned above, the State of Gujarat and Tamil Nadu have been shortlisted as potential markets for repowering:

3.1. Gujarat

Gujarat has a gross wind potential of 10,645 MW and a present installed capacity of 1500 MW. Gujarat is fast emerging as the hub for RE and the State has caught the fancy of the major wind players in the year 2009 and the installed capacity is expected to go up by 3000 MW in the next 3 years. Primary reasons for the spurt in investment are the attractive tariff declared by the GERC,[2] commitment of the Government of Gujarat to purchase 10% of its power from RE sources by 2012, economic viability of the sector (Gujarat is one of the few States where all public companies including distribution companies are in profit) and the availability of wind sites with economically viable CUF (around 18–20%).

Currently the on-shore market for Gujarat is attracting all the big investments from the private players. However, Gujarat has a huge repowering potential as well. The total capacity of wind machines installed in Gujarat before 1996 is 166 MW (*Source*: GEDA[3]). Applying a repowering factor (defined as ratio of new machines capacity to old machine capacity) of 3–4 (*Source*: Repowering experience in Denmark and Germany), there is a potential to create an additional capacity of more than 500 MW.[4] As per GEDA, there are more than 750 machines in Gujarat which were installed prior to 1996 and these machines would be the focus of any repowering effort. Also since Gujarat has the second highest tariff for wind energy in India, it makes Gujarat a very attractive State for investment in repowering.

Table 2 lists down some of the developers (companies) who had installed wind machines prior to 1996. Most of these players have a primary business and investment in wind project was a secondary investment in order to get an assured power supply for their businesses. Such players might of prime importance to investors/companies/financial institutions interested in repowering, as these businesses may have setup 220 kW of machines earlier but given the fact that such an investment was secondary, it raises a question whether these companies have the interest or the financial strength to install a machine 4 times bigger in size than their present ones. Possibly, these companies would be interested in maximizing their profits by either selling out the wind sites to

[2] Gujarat Electricity Regulatory Commission.

[3] Gujarat Energy Development Authority.

[4] A study needs to be carried out to gauge the actual market for repowering. Figure of 500 MW is grossly under estimated as the figure is based on thumb rules. Similar estimates for Tamil Nadu points to a repowering market of 2000 MW whereas study by WISE shows that there is a repowering potential of about 4200 MW in Tamil Nadu alone.

prospective investors or enter into a JV with them to invest in the repowered wind project.

3.2. Tamil Nadu

Tamil Nadu is the most successful State in terms of total wind capacity installed in India. Harnessing of wind energy is highest in Tamil Nadu with an installed capacity of 4136 MW, contributing 42.39% of the country's total installed capacity of around 9756 MW as on 31-1-2009. As per MNRE estimates, Tamil Nadu has a gross wind potential of about 5500 MW against which it has an installed capacity of 4136 MW. Tamil Nadu is fast approaching the upper limit of gross potential inside the State, yet the major players in wind energy continue to rally their support behind the State, indicating that the gross potential figure might have been under estimated. Also, there is another market available to wind energy players besides the Greenfield on-shore market which has been untapped so far, which is the repowering market.

Total capacity of wind machines in Tamil Nadu installed prior to 1996 is more than 500 MW, which are all highly attractive for repowering as these are the probably the best sites for wind energy in India. Assuming a repowering factor of 3–4, Tamil Nadu has a potential for addition of another 2000 MW through repowering. As per discussions with equipment manufacturers (Vestas and Suzlon), there are two specific wind-belts in TN (Muppanbal and Arulvoimuzhy) which alone have a repowering potential of about 1500–2000 MW.

However, the above estimates are based on thumb rules and not based on any field study. As per the World Institute of Sustainable Energy (WISE), which carried out a study of old wind machines (with capacity of 220 kW or less) totaling a capacity of 500 MW in Tamil Nadu, if the old machines were to be replaced with higher capacity machines, the electricity generated from the same area will go up by 2.5 times [1]. Based on their findings, WISE estimated that Tamil Nadu has about 1700 MW which can be repowered or replaced with higher capacity machines. This translated into a repowering market potential of about 4200 MW, which is quite significant. WISE also emphasized that a policy change is needed to incentivize the owners of aged turbines to go for repowering.

Clearly there is a huge untapped market for repowering with these two States alone having a repowering potential of about 5000 MW.

4. Financials

In this section, financial analysis of an investment into repowering is carried out in order to highlight the financial attractiveness of this business. The primary assumptions taken to perform the financial analysis for the Base Case are as follows:

- Based on our research, through interviews with equipment manufacturers and consultants, we understand that the Capex cost would approximately be INR 52 million/MW (GERC in its 2009 wind tariff order has suggested a capital cost of INR 46.2 million [3]).
- We assume a debt-equity ratio of 70:30 which is in line with the industry standards for RE projects as well as the standard followed by leading renewable financing agency in India (IREDA) and the same stipulation are considered by TNERC [7] and GERC in their respective wind tariff orders.
- We assume O&M cost as 1.5% of total capital cost with an escalation of 4%. Our assumption is in-line with what is followed by SERCs across different States.

Table 3
Cash flow from operation of a 2.1 MW wind machine.

	Year of operation							
	0	1	2	3	4	5	...	20
Cash receipts (INR million)		22.4	22.4	22.4	22.4	22.4	...	22.4
Cash outflow (INR million)							...	
O&M expenses		1.6	1.7	1.8	1.8	1.9	...	3.5
Interest on loan		7.3	6.5	5.8	5.0	4.3	...	0.0
Principal repayment for loan		7.6	7.6	7.6	7.6	7.6	...	0.0
Income tax		1.0	1.1	1.2	1.2	1.3	...	4.0
Total cash flow (INR million)	−32.7	4.7	5.4	6.0	6.6	7.2	...	12.2

Table 4
Income statement projection for operation of a 2.1 MW wind machine.

	Year of operation≫						
	1	2	3	4	5	...	25
Revenues							
Generation (MUs)	5.5	5.5	5.5	5.5	5.5	...	5.5
Revenue (Rs. million)	19.6	19.6	19.6	19.6	19.6	...	19.6
CERs (Rs. million)	0.0	0.0	0.0	0.0	0.0	...	0.0
GBI (Rs. million)	2.8	2.8	2.8	2.8	2.8	...	0.0[a]
Total revenues	22.4	22.4	22.4	22.4	22.4	...	19.6
Expenses							
Interest charges	7.3	6.5	5.8	5.0	4.3	...	0.0
Depreciation	4.37	4.37	4.37	4.37	4.37	...	4.37
O&M expenses	1.64	1.70	1.77	1.84	1.92	...	3.45
Income tax	1.01	1.09	1.17	1.25	1.33	...	3.96
Total charges	14.3	13.7	13.1	12.5	11.9	...	11.8
Profits	8.02	8.64	9.26	9.88	10.49	...	7.81

[a] GBI incentives are for a period of 10 years only.

- We assume an interest rate of 10% with a repayment period of 10 years with quarterly installments. Our assumption is in-line with what is followed by SERCs across different States.
- We have taken MAT (Minimum Alternative Tax) as 11.22% and Corporate Tax as 33.66%. These assumptions are as per government regulations
- Wind tariff in taken as Rs. 3.55/unit which is the wind tariff applicable in the State of Gujarat,[5] GBI[6] incentive is fixed by GoI at Rs. 0.5/unit. CER benefit at spot rates would be more than Rs. 0.5/unit, however we have taken a conservative estimate at Rs. 0.3/unit. In the Base Case, we consider revenue from wind power sale and GBI only, as CER approval is unsure at this point of time with Kyoto Protocol bound to end in 2012.
- We have calculated the cash flow and P&L for a project capacity of 2.1 MW and a CUF of 30% (refer Table 3 for projection of cash flow statement and Table 4 for projection of income statement).

Based on the above assumption, Base Case IRR from repowering a wind site comes out to be 22.6%. Cash flows are positive from the very first year of operation and the payback period of initial investment is approximately 5 years. Approval of application for CERs (Certified

[5] Wind tariff for the State of Tamil Nadu is Rs. 3.37/unit and a similar financial analysis could be carried out by the readers for investment in the State of Tamil Nadu.

[6] GBI: Generation Based Incentive [6] is the incentive scheme launched by GoI. Under GBI scheme, GoI is offering an additional tariff of Rs. 0.5/unit of generation, if the developer does not avail the accelerated depreciation benefits as declared by GoI earlier. Above a CUF of 18%, it is more beneficial to utilize GBI than to avail the tax ince ntive. Since CUF at repowered sites is more than 28%, GBI scheme significantly improves the IRR of a repowered project.

Table 5
IRR from the repowering operation for different capital costs.

	Capital costs					
	48	50	52	54	56	58
IRR (revenues from tariff + GBI)	26.6%	24.5%	22.6%	20.8%	19.2%	17.7%
IRR (revenues from tariff + GBI + CER)	30.7%	28.4%	26.2%	24.3%	22.5%	20.9%

Emission Reductions) to monetize carbon benefits can further enhance the financial attractiveness of the project and bring down the payback period to 4 years and increase the IRR to 26.2%.

Next, we evaluate the sensitivity of the project IRR to important project parameters. The factors having a significant impact on the IRR from the project are:

- Capital costs
- CUF of the wind sites

4.1. Capital costs

In this section, we showcase how the IRR of a repowering project changes with change in the capital cost of the project. We find that even with a higher capital cost of INR 58 million/MW, the IRR still comes out to be very attractive at 17.7%, better than what most Greenfield sites in India are currently offering. From the sensitivity analysis it can be observed that an increase in capital cost by INR 2 million results in a decrease in IRR by approximately 2% (Table 5). For financial investors, capital cost can include any premium they might have to pay to the present wind site owners in order to buy them out.

4.2. CUF of the wind sites

In this section, we showcase how the IRR of a repowering project changes with change in the CUF at the wind site. We find that even with a highly improbable CUF of 26%, the IRR of the project even in a worst case (not taking into account CER revenues) comes out to be 16.4%, which is financially very attractive. From the sensitivity analysis it can be observed that an increase in CUF by 1% results in increase in IRR by approximately 1.6% (Table 6). So the IRR of the project is quite sensitive to CUF at the wind sites and this is the reason why we included CUF at the project site as an important factor in shortlisting of wind sites for repowering.

Clearly, repowering a wind site is financially more attractive than investment in a Greenfield project which typically yields an IRR of 8–10%. The other attraction for investment in repowering would be the considerably reduced risks as compared to investment in a Greenfield project:

- *Land acquisition*: As discussed in Appendix A, land acquisition is a major barrier for installation of a wind project. However in repowering, the wind site is already available with the developer and hence land acquisition would not be a risk factor.
- *Evacuating infrastructure*: Transmission lines required for evacuation of power from renewable energy generators are typically not included by the Transmission Utility in their network plan and hence non-availability of evacuation infrastructure poses a significant risk. However, this risk is addressed since the lines for evacuating the power were already built by the previous owner for evacuating power from their old wind machines.
- *Uncertainty in wind velocity*: The old sites have been operational for over 10 years and hence we would have access to significant wind pattern data. Assuming the successful operation of the site and analysis of the data, we can assume that this risk would be non-existent.

Hence not only is the option of investing in repowering financially more attractive, it also entails reduced operational risks.

5. Future outlook

Financial analysis for an investment in repowering highlights that repowering of old-wind sites in India is financially attractive, even in the absence of additional financial incentives by Government of India. However, the current old-wind site owners are still not showing any intentions of repowering their wind machines. Some of the roadblocks in the opening of the repowering market and the concerns of the present wind site owners are discussed as follows:

- *Availability of good on-shore wind sites*: As discussed earlier, there are still good on-shore wind sites available in India and as long as there is availability of decent on-shore wind, sites repowering market would find it difficult to take-off. Typically wind projects are sold to investors by the end-to-end solution providers and they would not be actively interested in repowering until they are not able to sell any more Greenfield sites. Simple reason is because selling a repowering solution would require bargaining with multiple wind site owners (typically a single wind machine is owned by a single generator and to repower and install a larger wind machine, 2–5 wind machines need to be removed and hence negotiations with multiple wind site owners is required) and agreeing on valuation concerns.
- *Wind tariff applicability*: In India, the distribution companies enter into a buy-back agreement with the wind projects based on the feed-in-tariffs approved by the SERCs. However, not a single case of repowering has come before the SERCs so far and hence their reaction to repowering of a wind site is not known. While it is a common held perception that feed-in-tariff approved by the SERCs for the Greenfield sites would apply to the repowering projects as well, but there is no certainty in this matter.
- *Huge investment requirements*: As discussed earlier, many of the old-wind site owners had setup the wind projects to meet their

Table 6
IRR from the repowering operations for different CUF.

	CUF				
	26	28	30	32	34
IRR (revenue from tariff + GBI)	16.4%	19.4%	22.6%	25.8%	29.1%
IRR (revenue from tariff + GBI + CER)	19.4%	22.7%	26.2%	29.8%	33.5%

Note: Base case IRR is highlighted in the shaded portion.

captive electricity demand and since they have their primary businesses to manage, it raises a question as to whether they would be interested in committing to a huge investment in repowering. On the other hand, these old-wind site owners have the option of selling out the wind site to other investors; however such an option faces issues of agreeing on financial valuation of the wind site. Since the old machines are presently working, the owners of the wind site are demanding hefty valuations and hence the author believes that another 2 years would see a sudden spurt in repowering as the old machines would become non-operational and the site owners would be more open to negotiations.

- *Logistical issues*: Although the average wind turbine size is increasing, for logistical reasons there are real limits to the size of turbines that can be transported, particularly in on-shore markets. This is particularly true in Asia, where logistical issues will mean that the preference for smaller sized turbines will continue for some more time until there is better availability of transport infrastructure.

Despite the concerns mentioned above, the future holds promise for the repowering market in India. With time, in another 2 years, major concerns like availability of Greenfield sites, logistical issues, wind tariff applicability would be mitigated or addressed; end-to-end solution providers like Suzlon and Vestas would be more interested in providing repowering solutions as returns and availability from Greenfield sites reduce; and old-wind site owners would be more open to negotiating valuations as their old machines become non-operational.

With an IRR of more than 20% and a market potential of approximately 5000 MW in the State of Gujarat and Tamil Nadu only, repowering is bound to become an attractive investment opportunity in the future.

6. Case study

6.1. Germany [2]

Germany is a world leader in wind energy in terms of installed capacity. Since Germany is the largest wind energy user, it is reasonable to expect that Germany will also have a major market for repowering. The German Wind Energy Association (BWE) calculated that up to 2020, with a realistic approach, the on-shore repowering potential in Germany will be about 15,000 MW.

Before 2004, German feed-in-tariffs provided some encouragement for wind repowering, by offering new wind projects a higher payment than existing projects that had been operating for some time. Since 2004, the feed-in-tariff has offered a longer and higher payment level to wind turbines that replace/modernize existing project built before December 1995 and that are at least 3 times the capacity of the old turbine.

Given the fact that higher CUF wind sites in Germany were already harnessed and there was de-rating of machine capacity (i.e. lower generation from a wind machine due to deterioration of wind machine), the Government came out with an incentive scheme in order to promote repowering of wind sites [4]. Recent amendments in June 2008 ensured that EEG offered 0.5 cents/kWh above the initial feed-in-price of 9.1 cents/kWh for repowering projects. This will be effective from 1 January 2009. Eligibility criteria for the repowering incentive included that old turbines to be at least 10 years old and the new turbine needs to have at least twice, but no more than 5 times the capacity of the old turbine. The repowering bonus provided the incentive necessary for investment and replacing first generation turbines with modern and efficient converters.

Table 7
Repowering experience in Germany.

Repowering experience in Germany		Unit
Number of dismantled turbines for repowering	143	
Reduced capacity	59.3	MW
Number of new turbines installed after repowering	108	
New capacity	168.5	MW
Average capacity of dismantled turbines	415	kW
Average capacity of restored turbines	1560	kW
Reduction factor of number of turbines	0.76	–
Repowering factor	2.84[a]	kW/kW

Note: Base case IRR is highlighted in the shaded portion.
[a] Does not take into account gains from increase in efficiency of the wind machines.

In 2007, 108 old turbines were replaced by 45 new turbines. Despite this reduction, the overall output rose by a factor of 2.5 from 41 MW to 103 MW. Halving the number of turbines, but doubling their power and tripling the total energy yield has now become the new formula for success in the German on-shore wind energy sector (Table 7).

Despite this incentive, repowering has just begun and, given the regulations on siting, the wind industry argues that the feed-in-tariff repowering incentive is insufficient. Some other stumbling blocks for implementing repowering solutions include local government restriction on hub height or total turbine height, and setback requirements between installations and residential areas. Despite these barriers, the wind repowering opportunities in Germany are enormous.

6.2. Denmark

Denmark was the first country to actively support wind repowering, in part because wind turbine installation began in the early 1980s, so a large number of aging, small (<75 kW) wind turbines existed throughout the country. Denmark recognized that these smaller, aging turbines were an obstacle to new project development, and that removing and repowering those turbines would require an overt and explicit incentive. Denmark's repowering programme has led to repowering two-thirds of the oldest turbines in the country.

Denmark's first incentive programme for repowering wind turbines operated from April 2001 to December 2003. For turbines smaller than 100 kW, "repowering certificates[7]" allowed owners to install 3 times the capacity removed, and also provided for an additional feed-in-tariff price of 2.3 cents/kWh for the first 12,000 full load hours (about 5 years) of the enlarged wind project. For turbines in the 100–150 kW size range, owners could install twice the capacity removed, and receive the same treatment. As a result of this programme, 1480 turbines totaling 121.7 MW were replaced with 272 new turbines totaling 331.6 MW. Some owners of older wind projects also decided to decommission their projects and sell their repowering certificates to other wind developers.

Further, Denmark has continued to encourage wind repowering through a policy enacted via the energy policy agreement of March 2004. This new programme intends to repower another 175 MW of aging wind turbines. Under the programme, an extra surcharge is paid for new, on-shore wind turbines on the condition that the

[7] Repowering certificates: these replacement certificates enabled successful repowering in Denmark. The certificate holder is awarded a higher price for electricity produced from new turbines up to a maximum of two or three times the replaced capacity (depending on the replaced turbine name plate rating).

owner has a repowering certificate for a 450 kW wind turbine or less, decommissioned between December 2004 and December 2009. The surcharge is paid for factory new wind turbines connected to the grid between January 2005 and December 2009. The surcharge amounts to 1.6 cents/kWh and is paid for electricity production corresponding to 12,000 full load hours for up to twice the decommissioned wind turbine installed power. The surcharge is regulated in relation to the market price of electricity, and the total of the surcharge and market price must not exceed a specified level. Because of the current low price of wholesale electricity, wind industry stakeholders in Denmark are concerned about the adequacy of this incentive and are calling for a larger incentive.

As on December 2005, Denmark repowering program has led to repowering of approximately 2/3rd old turbines.

Appendix A

A.1. Alternative options in repowering

There are five options which can be typically used in repowering:

1. 1-to-1 up-scaling of solitary wind turbines;
2. 2-to-1 replacement, replacement of two smaller wind turbines by one large wind turbine;
3. Clustering of solitary wind turbines into farms; e.g. replacement of 20 solitary wind turbines by clustering 6–10 wind turbines at one location;
4. 1-to-1 replacement of wind turbines with similar rates but with newer machines;
5. 1-to-1 up-scaling of wind farms.

Each of the alternatives mentioned above have their own pros and cons. Alternative 1 leads to largest electricity production per unit area and alternative 4 the lowest. For alternatives 1–3 and 5, enhancing grid transmission capacity can be an issue and investment for upgrading the grid connection may be required, while for alternative 4 it is not necessary. For each alternative there is a positive impact on the landscape: the best one being alternative 3.

In the Indian scenario, the grid enhancement would not be a problem as the same is handled by the distribution companies and cost of enhancement is included in the project cost estimates used for financial analysis, the issue at hand would be generating the maximum amount of energy per unit of area and hence alternative 4 is ruled out. Alternatives 2 and 3 would require that multiple wind machines be replaced and multiple sites be combined to install a lesser number of higher capacity machines and such an option would require coordination between multiple site owners. Coordination issues have already been faced by end-to-end solution providers who have interacted with the site owners to convince them of repowering. Hence in the short term, till the old wind machines are functioning, the bargaining power of the site owners would be high and coordination issues would remain the primary road block and hence alternative 1 would stand out as the best option available for repowering. Once the market for repowering matures and the bargaining power of old-wind site owners diffuse, alternative 3 would become the flavor of the market.

A.2. Benefits of repowering

- *More power from the same area*: Wind power generation is multiplied without the need for additional land.
- *Fewer wind turbines*: the number of turbines can be reduced, enhancing the natural landscape. Also the construction height can be raised.
- *Higher efficiency*, *lower costs*: Modern turbines make better use of available wind energy and the cost of production (primarily operations and maintenance costs) is significantly lowered.
- *Better power grid integration*: Modern turbines offer much better grid integration, since they use a connection method similar to conventional power plants and also achieve a higher efficiency.
- *Wind speed and direction are known*: At an existing wind turbine location, wind speed and direction are already known, so it is easy to calculate the expected annual energy production for an existing location and hence it is easier to implement a repowering solution.

A.3. Risk associated with wind energy business

The following heads cover the entire gamut of risks involved with entering the wind energy business in India.

A.3.1. Pre-construction/project assessment risk

- *Uncertainty in wind velocity*: Uncertainty created by difference in expected CUF and the actual CUF in some of the recent wind plants in India has emerged as a key risk factor. Reduction in CUF by even 1–2% reduced the returns from the project by a very large amount.
- *Evacuating infrastructure*: Transmission lines required for evacuation of power from renewable energy generators are typically not included by the Central/State Transmission Utility in their network plan and hence non availability of evacuation infrastructure poses a significant risk in developing a wind site.

A.3.2. Project development risk

- *Land acquisition*: Land acquisition is a major barrier for installation of wind machines in India. A lot of wind projects in India have faced land acquisition problems in the years 2008 and 2009, particularly in the State of Maharashtra.
- *Project cost escalation*: Risk of project cost escalation is not very high, as a developer enters into a contract with the end-to-end solution providers and any escalation in project cost (due to delay in construction or any other reason) is absorbed by the solution provider.

A.3.3. Regulatory/tariff-related risk

- *Change in regulations*: Current regulations for power purchase from RE provide for an assured return on equity of 14%. Typically the methodology followed for tariff determination by SERCs includes taking a decision on different cost components of a generating station after consultation with all the stakeholders. After the different cost components have been determined, SERCs then finalize the tariff using a cost-plus approach using these cost components as benchmark for all the projects coming up in the State. Fig. 5 and Table 1 highlight the process followed by SERCs for determining the tariff for individual RE sources. Uncertainties relating to regulatory viewpoint in India acts as a risk factor for the wind energy market. Some SERCs are presently debating whether to allow for market determined tariff for wind projects, considering the fact that technology has quite matured. Any such can act as a major risk for developers of wind energy in India.
- *Change in tariff*: Any change in tariff by SERCs is applicable to new projects only and leave the tariff for power purchase from plants commissioned earlier unchanged. However, any change in

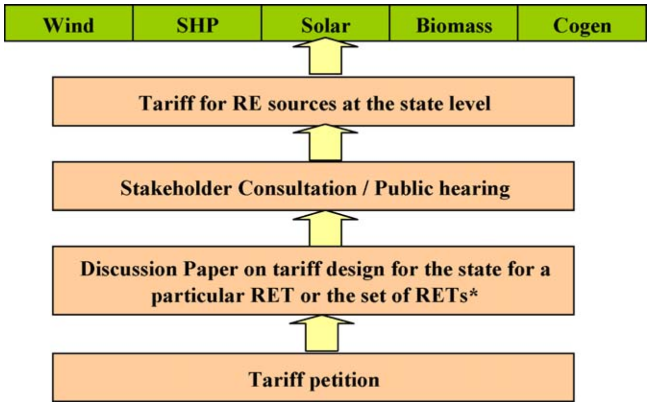


Fig. 5. Typical process followed by SERCs for determination of tariff for power procurement from renewable sources.

regulator's view on this issue is a risk factor for the wind developers.

A.3.4. Payment/off-taker's risk

- Most of the power off-takers (Discom(s)) in India suffer from poor credit and most of them even have negative cash flows. Hence the risk of default in payment i.e. off-taker's risk is high in India.

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